EK 103: Computational linear algebra (Spring 2023)

Our team of instructors:

Section	Times	Room	Instructor	Office hrs
A1 A4	TTH 9:30 am - 10:45 am TTH 11:00 am - 12:15 pm	PHO 210 PHO 210	Calin Belta cbelta@bu.edu	730 Comm Ave (EMA 218) TBD
A2	TTH 9:30 am - 10:45 am	PHO 211	Andrew Sabellas asabelha@bu.edu	110 Cummington (ENG 305) Tues 3:30 – 5:30 pm
A3	TTH 11:00 am - 12:15 pm	PHO 203	Tasso Kaper tasso@math.bu.edu	665 Comm Ave (CDS 533) TBD
A5	TTH 3:30 pm - 4:45 pm	PHO 210	Toshi Nishimura toshi16@bu.edu	725 Comm Ave (CAS 405) TBD
A6	TTH 5:00 pm - 6:15 pm	CAS 224	Kamal Sen kamalsen@bu.edu	44 Cummington (ERB 414B) TBD
A7	TTH 3:30 pm - 4:45 pm	PHO 203	Andy Fan fana@bu.edu	44 Cummington (ERB 707) TBD

Our graduate teaching assistant team:

TA	Email	The TA is assigned to this section	Joint office hours
Peter Crowley	petertc@bu.edu	A1 / A4 (Belta)	We will have "open" office hours where people can come in and ask questions on homeworks, matlab, etc! Tues: 6:15 – 8:15 pm ---> Room: PSY B45 Wed: 5:30 – 8:30 pm ---> Room: SOC B59 (Both rooms are along the big hallway in the basement of PSY / SOC)
Shuo Liu	liushuo@bu.edu	A1 / A4 (Belta)	
Meredith Anderson	merland@bu.edu	A2 (Sabelhaus)	
Haoxing Tian	tianhx@bu.edu	A5 (Nishimura)	
Jeffrey Alido	jalido@bu.edu	A5 (Nishimura)	
Kenny Kim	kennykim@bu.edu	A6 (Sen)	
Yifan (Joanna) Peng	ypeng9@bu.edu	A7 (Fan)	

Objectives: This is a course on understanding the fundamentals of modern data science, where we will learn how to manipulate and apply linear systems of equations in the context of matrices and linear algebra. Moreover, we will also try to think outside of the box and tease out some cool (and really useful) linear relationships among numbers, algebra, geometry, and calculus in an ***abstract*** fashion. Along the way, we will reinforce your ***programming*** skills because, after all, there's just way too much data for anyone to compute by hand in the 21st century !

Prerequisite

- EK 125: Basic programming skills (can be taken concurrently with EK 103)
- Algebra, trig, & geometry: You cannot be an engineer if you are scared of math ! You will be tested… =)

- A laptop that you can do homework on (with matlab installed)

Textbooks:

D.C. Lay, S.R. Lay, and J.J. McDonald: *Linear Algebra and its Applications (6th ed),* ISBN 978-0135851258

Note: You can also buy an used copy of the 5th edition of the textbook from Amazon. However, you will have to match up the table of contents between the 2 editions before every reading assignments.

Grading: Here's the lowdown (Homeworks are issued + due every Thursdays)

10%	Discussion attendance / participation / small quizzes
30%	Homeworks
20%	Midterm #1
20%	Midterm #2
20%	Final

Re-grading policy: Requests for regrading homeworks or exams must happen **within 1 week** from the day in which the material was handed back to you.

Note that grading of the assignments themselves will be done individually per section. Different instructors will use different scoring methods. ***Final letter grades may vary between sections, even if numerical scores are similar*** - each instructor may cover slightly different content. Also, late assignment policies vary by section. Check with your instructor.

Midterms:

There will be 2 Friday night midterms. If you have a scheduling conflict (ie. Physics / Chemistry /Calculus labs & exams), please let us know in advance (***10 day notice***) so that we can arrange for alternate exam dates and classrooms.

For each midterm, you are allowed to bring your computers, calculators, books, notes. You're also allowed to use matlab to help you compute matrices (or help to check your answers) during the exam.

** **Important:** See our academic integrity rules at the end of this document. Midterms are open-matlab but are ***not open-internet***. You will be asked to show all your work on the exams (ie. Writing calculation steps down on paper… which MATLAB cannot do that for you !!). Hence, if you want to do well on the midterms, you shouldn't plan to rely 100% on your computer to get you through the exam problems.

Furthermore, *for certain sections* (your instructor will give guidance in lectures), you might be instructed to bring your cell phone or tablet to the exam, where you will need those devices to scan your work and upload them onto Gradescope.

	Time	Location
Midterm #1	Fri 2/24/23 , 6:45 – 8:45 pm	To be determined
Midterm #2	Fri 4/14/23 , 6:45 – 8:45 pm	To be determined

Friday discussion sections (and the "small quizzes") :

We encourage everyone to attend our Friday discussion sections, where the TA's will:

a) ***Issue a small quiz*** during the middle of the session (it will count towards part of your 10% participation grade)
The purpose of the quiz is to help you know where you stand in terms of the lecture materials for that particular week (ie. Do I need to study more this weekend, or do I need to reserve more time to work on the next homework?)

b) They will also work out example problems that you might see on your homeworks and exams
c) They will also answer any questions you might have

In the past, students who chose to attend our discussion sections will often do better on exams (no joke – we keep statistics on this !) Just like any other class: The more practice problems you do, the better your grades will be !! =)

Course websites: There are 3 websites of interest:

1) EK 103 Blackboard site: Some instructors will use Blackboard. Those sections will announce on the first day of class. You may be asked to upload your matlab code there in addition to Gradescope. Grades may be synced to Blackboard or may only appear in Gradescope. Ask your instructor if you have questions.

2) Gradescope: Once we release the homework assignment PDFs on slack, you will submit them via Gradescope. Your homework and exam grades will also appear there. Your instructor should add you to their Gradescope page automatically. If you don't have access before the first homework is due, send your instructor a note.

3) EK 103 Slack workspace: **https://join.slack.com/t/ek103spring2023/signup**

This is where the main action is ! Just click on the line above and sign up. Then, from this site, you can:

- Download current versions of all homework sets, homework solutions, practice exams & exam solutions
- Get online help by asking us questions on lecture materials and homeworks

- The instructors and GSTs are only active on Slack at certain times. Some of us only answer questions during working hours (9am-5pm), and we may take a day or two to answer some questions. *Do not wait to ask questions at 2am* before the homework is due !!

There will also be separate channels for each section (for example, #a2_sabelhaus or #a5_nishimura). Ask questions specific to your instructor's policies there.

Academic integrity & collaborations on homeworks:

Don't cheat… just don't do it ! You will get into trouble if you are caught. For more information on BU's Academic Conduct Code (with examples on homework plagiarism), please follow this link:

BU's academic code of conduct:

http://www.bu.edu/academics/policies/academic-conduct-code/

We don't mind you working on homeworks and learning together with your friends, but when you are turning in your own homework, *you have to write the answers in your own words*. In general:

- You must clearly acknowledge all of your sources (including human collaborations) at the top of your homework
- You must write all answers in your own words
- Furthermore, ***you must be able to fully explain your answers upon demand from either the TAs or instructors (we will use this for cases involving misconduct disputes)***.

Failure to meet any of the above conditions could constitute plagiarism and will be considered cheating in EK 103. If you are not sure whether something is permitted by the course policy, please ask one of the faculty. It is far more awkward to explain your actions after the fact to the college disciplinary committee.

EK 103 (Spring 2023): Our class calendar, homework schedules, and weekly reading list

Week	Lectures (theme)	Topics	Readings (Lay, 6th Ed)	Homeworks: Usually issued and due on Thursdays !
Week 1 (1/19)	1 (basics)	Intro and course overview Vectors: Lengths, angles, and dot products	Ch. 6.1: pages 349 – 354 (up to Pythagorean Theorem)	
Week 2 (1/24, 1/26)	2 – 3 (basics)	Intro to matrices: How to multiply them using dot products; --- Matrices as linear transformations (Ax = b)	Ch. 2.1: pages 98 – 105 (especially the dot product methods in Examples 5, 6) --- Ch. 1.9: page 76 - 80 Example 3 on rotations, and the operations in Table 1-4	PS 1 issued Thurs 1/24
Week 3 (1/31, 2/2)	4 – 5 (Ax = b)	Systems of linear equations: Ax = b Solution existence + uniqueness for Ax = b Row reduction using augmented matrices [A b] Reduced row echelon form (RREF)	Ch. 1.1 Ch. 1.2	PS 1 due Thurs 2/2 PS 2 issued
Week 4 (2/7, 2/9)	6 – 7 (Ax = b)	Vector equations and span (Ch. 1.3) Ax = b as linear combo of column vectors --- Complete solutions to Ax = b Applications of Ax = b (balancing chemical equations, etc)	Ch. 1.3 Ch. 1.4 --- Ch. 1.5 Ch. 1.6	PS 2 due Thurs 2/9 PS 3 issued
Week 5 (2/14, 2/16)	8 – 9 (Ax = b)	Span, linear independence, and the homogeneous (nullspace) equation Ax = 0 --- Simple matrix operations (transposes, distributive properties, etc) Matrix inverses (part 1)	Ch. 1.7 --- Ch. 2.1 Ch. 2.2 Ch. 2.3: Theorem 8 (Invertible Matrix Theorem)	PS 3 due Thurs 2/16 No new PS issued on 2/16 b/c of exam
Tues 2/21		No class - Monday schedule (for President's day !!)		

Week 6 (2/23)	10 (Ax = b)	Matrix inverses (part 2) Matrix invertibility and its relationships with various properties of Ax = b in Ch. 1 and 2	Ch. 2.3: Theorem 8 (Invertible Matrix Theorem)	PS 4 issued Thurs 2/23
Fri 2/24	★	Exam 1 : Covers Lectures 1 – 8 (up to span + linear independence) and PSets 1 - 3		
Week 7 (2/28, 3/2)	11 – 12 Vector spaces + (Ax = b)	Brief overview of vector spaces + subspaces Nullspace N(A), linear independence, and Ax = 0 Column spaces: C(A) Row spaces: $C(A^T)$ --- Basis vectors + linear independence Dimensions, rank, and their relationship with the inverse of A	Subspaces readings: Ch. 2.8: pages 155 - 156 Ch. 4.1: pages 202 - 207 Nullspace and column space: Ch. 4.2: pages 211– 215 215 - 217 (table) Row space: Ch. 4.2: page 215 (Example 5) Basis vectors : Ch. 4.3, pages 222 - 224 Basis sets and pivot columns: Ch. 4.3: pages 225 – 228 (Examples 8, 9, 10, 11) Dimensions: Ch. 4.5: pages 241 -243 Rank of A (column space) versus A^T (row spaces): Ch. 4.5: pages 244 – 246	PS 4 due Thurs 3/2 PS 5 issued Thurs 3/2 (Will be a longer homework spanning over spring break, due Thurs 3/16)
Sat 3/4 - Sun 3/12		Spring break !!!!!!!! =)		
Week 8 (3/14, 3/16)	13 – 14 (Av = λv)	Intro to determinants --- Eigenvalues / eigenvectors (part 1)	Determinants: Ch. 3.1 Ch. 3.2 Ch. 3.3: pages 189 – 195 (don't worry about Cramer's Rule) --- Intro to eigenvalues: Ch. 5.1 Ch. 5.2: pages 282 – 285 (skip similarity and dynamical sys.)	PS 5 due Thurs 3/16 PS 6 issued

Week 9 (3/21, 3/23)	15 – 16 (Av = λv)	Eigenvalues / eigenvectors (part 2): Repeated eigenvalues / degenerate eigenvectors Diagonalizations	Diagonalizations and the proof of the <u>*eigenvalue equation in matrix form*</u> (AP = PD) on p. 291: Ch. 5.3: pages 290 – 291 Repeated eigenvalues and if it's diagonalizable or not: Ch. 5.3: pages 292 – 294, Examples 3, 4, 6	PS 6 due Thurs 3/23 PS 7 issued
Week 10 (3/28, 3/30)	17 – 18 (Av = λv)	Powers of A and diagonalizations: $A^k = P D^k P^{-1}$ Power method --- Markov chains and transition probabilities Google PageRank	Power of A: Ch. 5.3: pages 290, Example 2 The power method for finding dominant λ's and $\vec{v}$'s: Ch. 5.8: page 329 – 332 (skip "inverse power" method) --- Markov matrices: Ch. 5.9: pages 335 – 342	PS 7 due Thurs 3/30 PS 8 issued
Week 11 (4/4, 4/6)	19 – 20 Ortho-gonality	Projections onto a line --- Projection matrices $P = A (A^TA)^{-1} A^T$ Projections onto a subspace Least-squares (part 1)	Orthogonality and projections onto a line: Ch. 6.2: pages 358 – 364 --- Projections onto a subspace: Ch. 6.5: pages 382 – 386 (Figure 2 on p. 383 is the key diagram) Least-squares fitting: Ch. 6.6: pages 390 - 396	PS 8 due Thurs 4/6 No new PS issued on 4/6 b/c of exam
Week 12 (4/11, 4/13)	21 – 22 Ortho-gonality	Least squares (part 2) Applications of least-squares --- Orthogonal matrices Symmetric matrices and diagonalizations	Least-squares fitting: Ch. 6.6: pages 390 - 396 --- Orthogonal matrices "U": Ch. 6.2: pages 362 – 364 Diagonalizations of a symmetric matrix A: ($A = PDP^T$): Ch. 7.1: pages 419 – 421 (skip spectral theorem)	PS 9 issued Thurs 4/13

Fri 4/14	★	Exam 2 : Covers Lectures (1 – 18, up to Power method + Markov chains) and PSets 1 - 8		
Week 13 (4/18, 4/20)	23 – 24 (statistics SVD)	Quadratic forms + ellipses --- Intro to SVD (part 1)	Quadratic forms, symmetric positive definite matrices, and ellipses Ch. 7.2: pages 425 - 430 --- Ch. 7.4: pages 439 – 445 (stop at Example 4) Example 3: A = short + wide Example 4: A = tall + skinny	PS 9 due Thurs 4/20 PS 10 issued
Week 14 (4/25, 4/27)	25 -26 (statistics SVD)	Intro to SVD (part 2) Intro to statistics + Gaussian distributions SVD / covariance matrix / ellipses / statistics	Ch. 7.5	PS 10 due Thurs 4/27 PS 11 issued
Week 15 (5/2)	27 (statistics SVD)	SVD: Spectral decomposition and data compression	Ch. 7.5	
Wed 5/3		Last day of class… yaaaaaayy !!! =) (No lectures on this day)		PS 11 due Wed 5/3
Finals week (5/8 –5/12)	★	Final exam (to-be-determined date !)		